Synopsis V1.0
Proton SEE and TID tests report on ADV202 from Analog Devices

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I. Introduction

This study was undertaken to determine the proton total ionizing dose (TID) and proton induced single event effect (SEE) susceptibility of the ADV202 video compressor. The device was monitored for non-destructive and destructive events induced by exposing it to a 63 MeV proton beam at the UC Davis Cyclotron Single Event Effects Test Facility.

II. Devices Tested

The sample size of the testing was three devices. The devices were manufactured by Analog Devices. The devices tested had a Lot Date Code of 0351.

The device technology is 0.18µm CMOS.

III. Test Facility

Facility: UC Davis cyclotron
Energy: 63 MeV
Flux: ~ 8 x 10^6 to 7 x 10^8 particles/cm^2/s (beam current from ~ 50 to 4000 pA)
Fluence: According to the test plan, all tests were run in several steps up to a fluence of 1 x 10^{11} p/cm^2 or until functional events occurred.

IV. Test Conditions

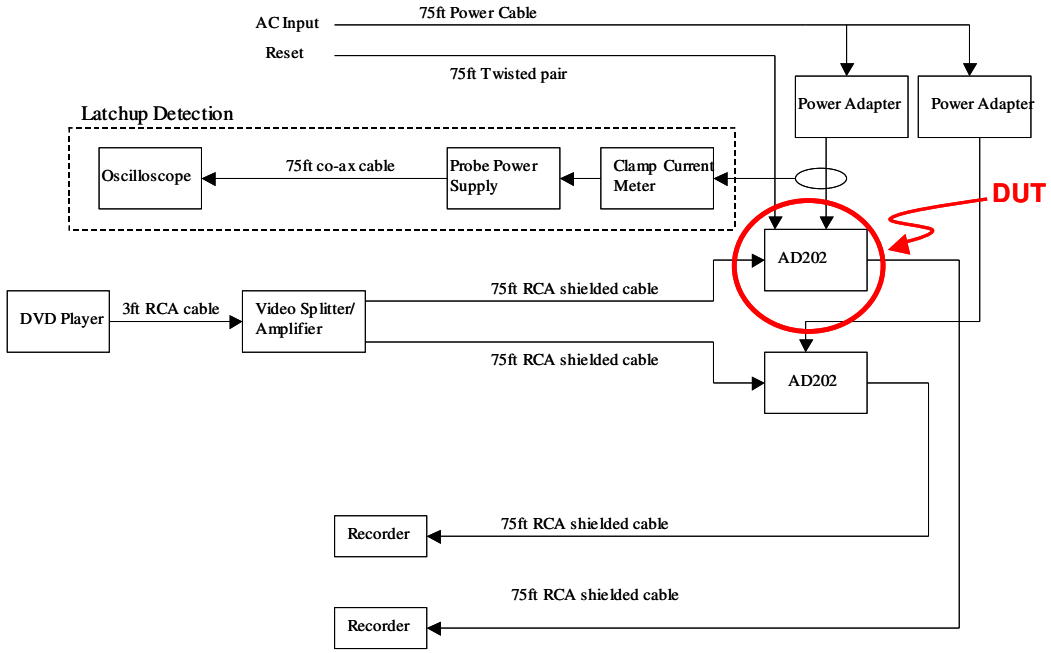
Test Temperature: Room Temperature
Power Supply Voltage: 1.5V (core and PLL), 3.3V (I/Os)

V. Test Methods

The JPEG2000 VidPipe ADV202 evaluation board was used for the test. It supports different video input or output formats. After decoding, the input signal is compressed with the ADV202, a second ADV202 chip in the board decompresses the image that is sent to the output after encoding. A Blackfin ADSP533 controls the compression/decompression operations. An USB interface allows the control and monitoring of the board. More details about the evaluation boards are given in the test plan.

Test set-up is shown in Figure 1. A computer generated test image, stored in a DVD player, acts as the test pattern. The image is fed from the DVD player to a splitter/amplifier and then down to two parallel paths, one to the ADV202 DUT and one to the ADV202 control. The DUT and control each compress their signals and output them to PCs designated for each path. Recorders on the DUT and control paths simultaneously capture the output data, and the images are displayed on each PC's monitor for the observer to view in real time. The PCs also record the output images for further analysis after the irradiation.

Each ADV202 board (DUT and control) has separate power inputs. Power to the DUT is monitored via an oscilloscope.



ADV202 Test Setup

Figure 1. Overall Block Diagram for the testing of the ADV202.

Three different computer generated test images were used:

- a computer generated test pattern, "Pattern,"
- a dark image, "black,"
- and a light image, "white."

VI. Results

Irradiation test sequence and a top-level summary of results are given in the Table in Appendix. The salient results obtained from this testing are:

- No visible permanent degradation was observed on all three parts. The total accumulated dose is 13.5 krad-Si on DUT 1 and 2, and 71 krad-Si on DUT3.
- No destructive event was observed during all irradiation runs.
- A significant number of image loss events were observed. Three different loss of image types were observed: black screen, image severely degraded, or continuous image flipping. In all cases the DUT did not recover by itself or with a soft reset, but did recover with a power cycle.
- Other transient events were also observed: distortion of image, color loss, or image flipping that recovers by itself.

We focused the following analysis on image loss events. We did not use the data on DUT3 because these tests were performed at high flux, and the image flux occurred as soon as the irradiation beam was on. Therefore, there is a large uncertainty in the event cross section measured on this device. We tried to look at the recorded data, but it did not help because it is not possible to define exactly the start of irradiation runs. We were able to get cross section information for most of the irradiation runs in DUT1 and 2. Data is shown in Table 1. The average cross-section for DUT1 is about 8×10^{-10} cm^2/device. The average cross-section for DUT2 is about 5×10^{-9} cm^2/device. This sensitivity is quite high. The proton induced image loss event rate on the HST orbit will be of the order of one every two weeks for each device.

There are two possible causes for these image loss events:

- A Single Event Functional Interrupt (SEFI): the device stops functioning because of a SEU in a control register, within the DSP probably.
- A non-destructive Single Event Latchup (SEL) or a micro latchup. No increase of the DUT board was observed during irradiation. Therefore, if the image loss were due to a latchup, it would probably be a microlatchup.

Run #	DUT #	Energy (MeV)	I beam (pA)	time (sec)	fluence (#/cm2)	image loss #	image loss cross-section (cm2/dev)
1110	DUT 1	63.3	51.7	77	6.60E+08	0?	
1111	DUT 1	63.3	50.4	138	1.18E+09	1	8.47E-10
1112	DUT 1	63.3	49.7	72.6	6.27E+08	1	1.59E-09
1120	DUT 1	63.3	50.9	291	2.50E+09	1	4.00E-10
1130	DUT 1	63.3	110	290	5.00E+09	2	
				40	6.90E+08	1	1.45E-09
				130	2.24E+09	1	4.46E-10
1140	DUT 1	63.3	211	272	1.00E+10	2?	
				100	3.68E+09	1	2.72E-10
				30	1.10E+09	1	9.07E-10
1150	DUT 1	63.3	416	278	2.00E+10	1	
				50?	3.60E+09?	1	
1160	DUT 1	63.3	800	140	2.00E+10	1	
				3?	4.29E+08?	1	
1161	DUT 1	63.3	801	288	4.00E+10	?	
2110	DUT2	63.3	52	290	2.50E+09	1?	
				7?	6.03E+07?	1	
2120	DUT2	63.3	49	50	4.18E+08	1	2.39E-09
2121	DUT2	63.3	51	11.5	9.66E+07	1	1.04E-08
2122	DUT2	63.3	48	52	4.36E+08	1	2.29E-09
2123	DUT2	63.3	50	16	1.34E+08	1	7.46E-09
2124	DUT2	63.3	48	163	1.40E+09	0?	
2130	DUT2	63.3	101	293	5.00E+09	0?	
2140	DUT2	63.3	217	267	1.00E+10	0?	
2150	DUT2	63.3	427	278	2.00E+10	1	
				80?	5.76E+09?	1	
2160	DUT2	63.3	807	427	6.00E+10	1	
				?		1	

Table 1: Image loss data

VII. Further Test Requirements

A heavy ion test is strongly recommended. The heavy-ions may cause other single events effects that were not observed with protons like destructive SEL. In addition, heavy ion contribution to the image loss rate is expected to be significant.

VIII. Conclusion and Recommendations

With a tolerance greater than 70 krad-Si, ADV202 video compressor meets HRV TID requirements. As far as SEEs are concerned, devices are generally categorized based on heavy ion test data into one of the four following categories:

Category 1: Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2: Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3: Recommended for usage in some NASA/GSFC spaceflight applications, but requires extensive mitigation techniques or hard failure recovery mode.
Category 4: Not recommended for usage in any NASA/GSFC spaceflight applications.

We will have to wait for heavy ion test to make a definitive categorization. But, based on these proton data, ADV202 is already a category 3 device with a power cycle needed about every two weeks for each device.

Appendix 1:

Test log

DUT	Energy (MeV)	I beam (pA)	Time (sec)	inc. fluence (p/cm^2)	tot. fluence (p/cm^2)	inc. dose (rad-Si)	tot. dose (rad-Si)	Comments
ADV-202 DUT 1	63.3	51.7	77	6.60E+08	6.60E+08	88.9	88.9	first run to 2.5 E9 interrupted to reset DUT - lots of drop-outs -self recovery
ADV-202 DUT 1	63.3	50.4	138	1.18E+09	1.84E+09	160	248.9	run interrupted to reset DUT - could not soft reset - cycle power to recover
ADV-202 DUT 1	63.3	49.7	72.6	6.27E+08	2.47E+09	84	332.9	run interrupted to reset DUT -lots of drop-outs - could not soft reset - cycle power to recover
ADV-202 DUT 1	63.3	50.9	291	2.50E+09	4.97E+09	337	669.9	2nd run sequence - lots of drop-outs - lost image near end of run, no soft reset, power cycle to recover
ADV-202 DUT 1	63.3	110	290	5.00E+09	9.97E+09	673	1342.9	3rd run sequence - lots of drop-outs - lost image twice during run, no soft reset, power cycle to recover while beam on, see color noise, image instability after run couldn't clear with reset, clears with power cycle
ADV-202 DUT 1	63.3	211	272	1.00E+10	2.00E+10	1350	2692.9	4th run sequence - lots of drop-outs - lost ? times during run, no soft reset, power cycle to recover while beam on, see color noise, image instability after run couldn't clear with reset, clears with power cycle
ADV-202 DUT 1	63.3	416	278	2.00E+10	4.00E+10	2700	5392.9	5th run sequence - lots of drop-outs - lost image during run, didn't stop beam, image lost after run couldn't clear with reset, clears with power cycle
ADV-202 DUT 1	63.3	800	140	2.00E+10	6.00E+10	2700	8092.9	6th sequence first third
ADV-202 DUT 1	63.3	801	288	4.00E+10	1.00E+11	5390	13482.9	6th sequence, rest of the run, didn't worry about lost image during run, recovers with power cycle at end of run
ADV-202 DUT 2	63.3	52	290	2.50E+09	2.50E+09	337	337	saw similar to DUT1, but did not stop beam when lock-up was registered
ADV-202 DUT 2	63.3	49	50	4.18E+08	2.92E+09	56	393	saw similar to DUT1, but did stop beam when lock-up was registered

ADV-202 DUT 2	63.3	51	11.5	9.66E+07	3.01E+09	13	406	saw similar to DUT1, but did stop beam when lock-up was registered
ADV-202 DUT 2	63.3	48	52	4.36E+08	3.45E+09	59	465	saw similar to DUT1, but did stop beam when lock-up was registered
ADV-202 DUT 2	63.3	50	16	1.34E+08	3.58E+09	18	483	saw similar to DUT1, but did stop beam when lock-up was registered
ADV-202 DUT 2	63.3	48	163	1.40E+09	4.98E+09	189	672	saw similar to DUT1, finished run without requiring a soft reset
ADV-202 DUT 2	63.3	101	293	5.00E+09	9.98E+09	674	1346	reset multiple times during run, never required power cycle and finished run in good shape
ADV-202 DUT 2	63.3	217	267	1.00E+10	2.00E+10	1346	2692	never required power cycle and finished run in good shape
ADV-202 DUT 2	63.3	427	278	2.00E+10	4.00E+10	2696	5388	required power cycle at end of run
ADV-202 DUT 2	63.3	807	427	6.00E+10	1.00E+11	8091	13479	required power cycle at end of run - test sequence complete
ADV-202 DUT 3	63.3	100	145	2.50E+09	2.50E+09	336	336	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	100	148	2.50E+09	5.00E+09	337	673	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	216	134	5.00E+09	1.00E+10	673	1346	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	440	139	1.00E+10	2.00E+10	1352	2698	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	870	43 or 73?	1.00E+10	3.00E+10	1349	4047	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	807	507 or 537	7.00E+10	1.00E+11	9430	13477	run at twice the flux, don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	2122	267	1.00E+11	2.00E+11	13460	26937	don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	2319	267	1.00E+11	3.00E+11	13460	40397	don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	2097	267	1.00E+11	4.00E+11	13460	53857	don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	4252	142	1.00E+11	5.00E+11	13470	67327	don't stop for hangs, reset with power cycle after run
ADV-202 DUT 3	63.3	4188	340	2.50E+11	7.50E+11	3367	70694	don't stop for hangs, reset with power cycle after run - still resets after 100 krad - end test and move to next setup